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PSYCHOLOGICAL AND EDUCATIONAL FACTORS IN TRANSFER OF TRAINING, PHASE I. FINAL REPORT.

BY- STOLUROW, LAWRENCE M.
ILLINOIS UNIV., URBANA, BUR. OF EDUC. RESEARCH
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A FINAL REPORT WAS MADE OF THE ACTIVITIES PURSUED IN PHASE 1 OF A 10-YEAR PROJECT DEALING WITH THE PSYCHOLOGICAL AND EDUCATIONAL FACTORS INVOLVED IN TRANSFER OF TRAINING. PHASE I CONSISTED OF A SURVEY OF THE EXISTENT DATA AND CONCEPTS OF TRANSFER OF TRAINING IN AN ATTEMPT (1) TO SUMMARIZE, INTEGRATE, CONSOLIDATE, AND INTERPRET RESEARCH FINDINGS AND THEORY AND (2) TO CONSIDER THESE FINDINGS IN RELATION TO THE PROBLEMS OF EDUCATION TO PRODUCE A SET OF HYPOTHESES FOR RESEARCH AND A WORKABLE PLAN FOR CONDUCTING STUDIES RELATED TO THOSE HYPOTHESES. LIBRARY RESEARCH PLUS THE ANALYSIS AND SYNTHESIS OF EXISTING INFORMATION AND CONCEPTS RESULTED IN ABSTRACTS OF REPORTS, ARTICLES, MONOGRAPHS, AND BOOKS AND THE PREPARATION OF AN INTERPRETIVE SUMMARY. PRELIMINARY EMPIRICAL RESEARCH WAS CONDUCTED, AND SUMMARIES OF STUDIES DEALING WITH SEQUENCING, LEARNING HOW TO LEARN, AND MEDIATION THEORY WERE PRESENTED. THE RESEARCH PLAN FOR PHASE 2, WHICH WAS GENERATED BY THE WORK PERFORMED IN PHASE 1, WAS DESCRIBED. THE PROCEDURE IN PHASE 2 WILL BE ASSOCIATED LESS WITH LIBRARY RESEARCH THAN IT WAS IN PHASE 1. THERE WILL BE A MARKED INCREASE IN THE AMOUNT OF EMPIRICAL RESEARCH DESIGNED TO ELUCIDATE TRANSFER PROBLEMS AND PROCESSES. (GD)

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TRAINING RESEARCH LABORATORY

Department of Psychology Bureau of Educational Research
University of Illinois 8 Lincoln Hall Urbana, Illinois

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Phase I

Final Report

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Lawrence M. Stolurow
Professor, Department of Psychology
Bureau of Educational Research

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Introduction

THE NATURE OF THE PROJECT

Despite more than 60 years of research on transfer (Thorndike and Woodworth's study was in 1901), there is little definitive information or explicit guidance to offer either the course developer, the curriculum builder, or the media specialist. The need for information about transfer is critical for the efficient planning of courses, curricula, and media for education. The problems, procedures and prospects of research on transfer are in critical need of substantial study from a fundamental point of view.

This project was developed to provide information about transfer as a psychological and as an educational process. The current problem is not only the lack of available information about transfer, but also the failure of existent information to be linked to either the educational or the training-decision processes to which it can and should contribute.

OBJECTIVES

Phase I

Phase I of this project has the following objectives. One is to develop hypotheses about the nature of transfer and variables affecting it. In doing this, an organized evaluation of available experimental and theoretical studies of transfer will be accomplished in a preliminary manner along with the compilation of bibliographies of research and theory, including the relationships between learning and transfer, the relationships between transfer, abilities, and aptitudes, and the relationships between transfer and problem solving. A second objective is to formulate principles of transfer as they relate to particular educational media, methods, and practices. A third is to conduct preliminary transfer studies appropriate and necessary to determine the feasibility of particular research applications of the new media. A fourth is to formulate plans for a research program to be conducted in the second phase to determine the relationship of transfer of training to educational processes and media.

Phase II

Phase II, which will not be covered here, has the following objectives: (1) to implement the plan of research on transfer of training in relation to educational processes and media developed in Phase I, and (2) to prepare manuscripts for publication from the materials developed for objectives 1, 2, and 3 of Phase I.

Chapter I

OBJECTIVE 1: HYPOTHESES ABOUT THE NATURE OF TRANSFER AND VARIABLES AFFECTING IT

TWO TYPES OF TRANSFER

Specific Transfer

The type of transfer dealt with by Thorndike and Woodworth (1901) is the psychological process which is evidenced by performance on a later task that has perceptual elements in common with a task learned earlier. Two variations can be identified in terms of effects on performance since the student having learned the first task, can perform either better or worse on the second task. The apparent "carry over" of the effects of prior learning is called transfer of training. Those situations in which it can be related to common features or elements of the stimulus materials (specific transfer) have been studied most extensively; however, they may be both less commonly found in non-laboratory situations and less interesting as educational phenomena than non-specific transfer. Since it is described and well documented in many available references, it will not be explicated here (e.g., McGeoch and Irion, 1952; Osgood, 1953).

Non-Specific Transfer

The more ubiquitous, though less often studied form, is non-specific transfer. It is transfer, either positive or negative, which appears to be cued by relational, structural, and/or formal (abstract) features of stimulus materials, features not usually represented in a single discriminable element. They can, however, be described as analogies, metaphores, algorithms, congruities, and incongruities. Non-specific transfer is assumed to be mediated by a process (a response or set of responses) which serve to relate perceptually distinctive and often perceptually different materials to behavioral outcomes.

Approach

A useful beginning for a research program in this area is with the data, methods, and concepts of transfer as they have been developed from the common elements point of view. However, it is assumed that this is insufficient for generating principles for education since it appears that the data and concepts are too limited. For example, abilities or aptitudes are assumed to be highly relevant to complete analysis of transfer as it relates to performance within courses of instruction and between them. Therefore, for the purpose of this project, two assumptions were made. First, there is a fundamental relationship between the learning theorist's conception of mediation and the psychometrician's conception of abilities. Second, there are at least three basic characteristics of complex tasks (quality, texture, and structure)[1] that determine transfer effects which occur both within and between the tasks.[2]

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[1] These terms are explained later on page 8.

[2] Tasks are specified in terms of the characteristics of the input to the student (e.g., the nature of the stimuli and their sequence) and the performance standards for judging the correctness of the learner's responses to individual inputs.

The first of the above assumptions is based upon a logical analysis of the concept of mediation as an association (or set of them) that links an explicit set of stimuli to a set of responses and upon the definition of ability as something a person does in the presence of a specified set of materials which predicts future achievement in a number of situations of a specified type.

The second assumption can be analyzed similarly. Very briefly, it is that transfer may be viewed as a process in which the cues for response include those that do not have common identical elements, e.g., formal similarities.

Contrary to the common elements point of view is the common perceptual elements conception wherein the elements common to two or more tasks are characterized perceptually; this view can be called a generalized-process view. Since it is a more general conception of the mechanisms accounting for transfer, it embraces formal or relational communalities as well as perceptual communalities. It assumes that perceptually dissimilar stimuli can cue common responses; and, also, that stimuli which contain class descriptive cues (Stolurow, 1956) may be associated with a common response. The common feature between tasks that could account for transfer effects (either positive or negative) is the common response, e.g., a metaphore.

Specific and Non-Specific Transfer

It is assumed that the mechanisms which account for transfer are of two basic kinds. One kind is content-specific and usually studied in research relating to the common elements theory of transfer (Thorndike and Woodworth, 1901). The other kind is process specific and usually studied in relation to a skill. Therefore, the distinction between the types of transfer (specific and non-specific) lies in the nature of the relationship between or among a set of tasks. In the research on the common elements theory of transfer, the individual perceptual elements are common to the tasks. An example is the number of common letters in words. In Harlow's learning-set studies (1949), the relationship is not provided by a cue stimulus but, rather, by a stimulus that follows the learner's response *and* is contingent upon the nature of the response. The stimulus materials used in Harlow's discrimination learning set studies do not have a common perceptual element running through the set of paired objects (e.g., red color, or round form); instead, the stimulus objects can be any pair. In fact, if an element were common to the perceptual characteristics of two or more sets, it would change the task in terms of non-specific transfer. In addition to teaching each specific discrimination, the early discriminations involving "junk stimuli" taught the concept that one, and only one, stimulus object in every pair is followed by a reinforcement stimulus. Once this concept is learned, the learner is shown a new pair of objects, selects one, and, if he obtains reinforcement, continues to select the member of the pair. If his response is *not* reinforced, then he inhibits that response and selects the other stimulus object on the next trial. The cue to persist in his original selection is the *presence* of the reinforcement stimulus following his response; the cue to change to the other object is the *absence* of the reinforcement. Thus, once he has learned that one object is followed by reinforcement, only one trial is needed to solve any new discrimination. The common element is not in the discriminanda (the stimuli preceding the response) but rather in the reinforcement, the stimulus that follows response. The fact that the critical cue is response dependent, rather than an aspect of the discriminanda, makes the transfer more general. It is more general in the sense that the critical cue is characteristic of a set of learning experiences that can be different in all other respects.

A GENERALIZED-PROCESS VIEW OF TRANSFER OF TRAINING

The basic studies which relate to a generalized view of transfer of training from one task to another include forms of stimuli that are relatable in terms of common formal elements. They also include those that are relatable by means of perceptually common elements which serve as cues. Studies of cumulative transfer are relevant to this view since the student is confronted with a set of tasks, homogeneous with respect to their formal properties from which he can acquire "learning sets" (see Harlow, 1949; Gagné and Paradise, 1961). In other words, the matrix in which the stimuli are imbedded (see Grant, 1964) is the same from task to task, but the stimuli vary. From working with a set of problems said to be homogeneous, the student learns to respond in a particular way to a class of objects in a specific context. Homogeneity of stimuli as used in this context, refers to a formal similarity among a set of learning tasks,[3] e.g., the discrimination of object quality or oddity.

Quality, Texture, and Structure

The particular set of associations which a learner acquires constitutes what is meant by the qualitative nature of the learning that has taken place. Learning sets are associations that are common to a variety of physically different but formally related stimuli. One type of formal relationship among associations is called attitudinal; this involves both sets of objects or symbols as cues and their affective or emotional responses. This type of learning set is dispositional in the sense that it involves approach or avoidance responses to specific cues or to classes of cues. Another type if psychomotor; this involves both perceptual stimuli as cues and overt, observable motor responses. This type of learning set is constituted of skills and generally involves visible, overt responses. A third type is cognitive; this involves both sets of cues and responses that produce stimuli which have meaning for other persons. This type of learning set is substantive in nature in the sense that the critical cues and responses are content related.

A particular group of learning sets, of whatever type or types, that is the distinctive qualitative set acquired by a learner is the texture of his learned behavior. The learners may acquire a number of learning sets that are qualitatively the same but they may differ in their textures by having some different qualitative features. For example, one student may not acquire the attitudinal set acquired by the other although both were taught the same task. The texture of behavior which the student learns may include one or more of the possible qualitatively different learning sets. Thus, two students learning the same task may acquire behaviors that differ in texture, but they may earn the same score on a test of achievement because each may acquire the same number of learning sets although not the same learning sets. Mastery of a task increases the probability that all learners have repertoires with the same texture. Below-mastery compensation or tradeoff is possible, and a summary score does not reveal the differences in texture.

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[3] This means that one statement is sufficient to describe the relationship between the stimuli in every set (e.g., every pair, every triplet) to which the learner is to respond, and a response set can be described by a single rule or principle that is sufficient to describe the relationship common to the set of stimuli.

In the learning of complex behavior repertoires, it is assumed that students will acquire qualitative components at different rates so that the texture of their repertoires at any point in time will show considerable variation in concepts (content learning set), attitudes, strategies (methods of attack), and possibly some psychomotor skills. Different learners will actually acquire the individual learning sets to varying degrees of proficiency if they are all taught in the same way. Thus, the development of learning sets is a variable outcome of the particular learning experiences provided to the learner, and methods of providing them will differ in the range of variation produced among a group of learners. While the individual learning sets are mastered to different degrees, those that are mastered to minimal criteria levels constitute the qualitative elements of the learner's repertoire and thereby its behavioral texture. However, the texture of a learner's behavior does not specify interrelationships among the qualitative elements.

Hierarchical transfer is transfer from lower level learning sets to higher level learning sets within a subject matter domain. The structure of behavior refers to the interrelationships among learning sets such as hierarchical relationships that exist among a group of learning sets (e.g., Gagné and Paradise, 1961; Merrill, 1965). Each hierarchy of learning sets has a pattern and a distinctive form which is a result of the conditions of learning and the degree of overlearning and is specified by the cueing of textural elements. Qualitative learning sets, including content, attitudinal, and psychomotor types, may all be involved in a particular hierarchical structure. Each, presumably, is cued to at least one of the others in a pattern that is sequential or that is represented by a hierarchy. It is assumed that a hierarchy of learning sets is developed through cueing; however, the pattern of interrelationship which develops for a particular learner may not agree with the formal analysis of the subject matter and the intent of the teacher. Furthermore, the learning sets may not develop from lower to higher levels and, in fact, probably will not unless the conditions of learning, particularly the sequences, are properly engineered. An example of ineffective cueing of learning sets has been reported by Stolurow, Hodgson, and Silva (1956). Whether the particular learning sets that give behavior its texture also constitute an associative structure depends upon the extent to which the constituent learning sets are cued to one another. If they are not, then the behavior has texture but not structure.

Aptitudes, Mediation Process, and Transfer

In formulating a model of individual teaching that can accommodate this conception of transfer, it was assumed that the processes measured by ability tests and the processes postulated by the learning theorist to account for the acquisition and transfer of knowledge and skills were the same. In this respect, the model is consonant with the theoretical positions of Ferguson (1954, 1956), Osgood (1953), and Guilford (1950). The underlying hypothesis is that when the skills and mechanisms developed while learning a variety of tasks with a common structure are overlearned, they become the abilities and aptitudes that are measured by tests of individual differences. From sets of structurally-related tasks, the learner learns how to learn (e.g., Harlow, 1949) tasks of that type which means he can more readily acquire new cue-response relationships involving the same formal property. It is further assumed that a great deal of the learning how to learn effect is achieved simply because the same processing skills are involved in all the tasks. Thus, the transfer effects are due to something other than common perceptual elements. Consistent with Ferguson's position, it is assumed that overlearning brings these patterns of behavior to a level at which they become relatively invariant, and at some minimal level of invariance these behavior patterns can become apparent through performance on tests which are called ability and aptitude tests. The contribution of these relatively-invariant behavior patterns to the learning of new associations is their transfer effect. Thus, aptitude and transfer are highly-related;

aptitude is the potential for transfer that the individual acquires through learning. It is the set of cue-performance relationships that predicts future performance on a new task or, in other words, the current abilities that predict performance on a new task -- transfer.

Processing Skills

It is assumed that all learning involves mechanisms which can be called processing skills. These skills aid the learner in acquiring associations in structurally similar situations as well as in those containing common perceptual elements. Included are receptor orientating skills; e.g., eye movements.

Overlearning of processing skills comes about by the learning of specific skills that fall into classes or sets of experiences which, while they may differ in detail, nevertheless involve common formal elements such as represented by the simple, and now classic, cases of transposition and oddity. The development of learning sets despite the variety of stimulus conditions (cue-response learning) is explained by the presence of cue-response sets that have some formal or relational elements in common. While this appears to be a reasonable hypothesis, as suggested by the research of Harlow (1949) on learning sets, the actual mechanism which provides a sufficient behavioral condition represented by the formal property held in common (by oddity problems for example) is not always easy to identify. In the discrimination learning set, for example, the learner simply responds to individual features of the displays, or to sets of them, as cues. If he is correct, he continues to use the cue; if he is wrong, however, he shifts to another cue. In other words, knowing that one is wrong means that another characteristic of the stimulus set is to be used as a cue.

Types of Molar Cues

There are several types of molar cues that the student learns initially as stimulus-response associations. Once learned, they serve to cue other responses. These are structural features of tasks of which there are a variety.

Response dependency of reinforcement as a task characteristic. In addition to the several characteristics of tasks previously identified (Stolurow, 1964), the presence or absence of reinforcement can be a critical task cue. In other words, for some tasks, the sufficient cue is in the stimuli preceding response, whereas for others it is also the stimuli that follow the response.

Formal similarity can act as a cue. The critical aspects of a set of stimuli may be the common context in which they appear as well as in the events following response. A structural feature of tasks (a relationship between or among stimuli) can acquire a cue function in the same way that a physical property of an object does. A structural feature can be a cue and can elicit a response or a response chain; the set of stimuli that are the structural features of a task can account for transfer from otherwise dissimilar-appearing tasks.

Verbal pattern as a cue. There are many structural characteristics of tasks such as forms in music, poetry, or prose (e.g., a chord, a sonata, a sonnet, a simple declarative sentence, a dialogue). Each of these can become a cue or an aspect of a complex cue for a particular response as is evidenced by the sheer fact that these forms can be reliably discriminated. The structure of a task can be a cue for response and is potentially useful as a basis for transfer, for it can serve as the common element between or among a set of otherwise dissimilar tasks in the same way as a physical or perceptual characteristic which is common to a set of tasks. The structures of grammar, of mathematical proofs, and of syllogisms, for example, while more difficult to discriminate, nevertheless illustrate the potential cue value of formal properties in transfer. Their actual significance for transfer is not well known since they have been neglected as the focus of research on transfer. However, the structural features of tasks have the potentiality of functioning in the development of important learning sets. The relative potency of structural features of tasks depends upon both the development of important learning sets and the relative salience of the critical features as compared with the perceptual features with which they are in competition for the learner's attention. Furthermore, if the structural features of tasks are to become cues, then two or more sets of stimulu have to be combined since structural features are coded as a relationship (e.g., syllogism). Memory also is involved since the discriminandum has to be recognized as having been associated with reinforcement.

Structural features as cues. The structural characteristics of tasks can be studied as the common element which accounts for transfer from otherwise apparently diverse learning experiences. For example, Crutchfield and Covington's (1963) successful use of programed-learning experiences involving mystery stories, as a means of improving the problem-solving performance of students on Dunker types of tasks (which have no common content with the learning experiences), illustrates the potential transfer value of skills cued by formal or structural characteristics of the learning experiences in spite of semantic differences.

Learner supplied labels as cues. Even the labeling of something as a problem can elicit the repertoire of problem-solving responses which the learner has acquired. A label identifies a structural communality that can be the cue for responses. In fact, the label can serve as a symbol representing the more complex formal similarity. The responses elicited may be simple and insufficient or they may be complex and sufficient. Whatever their state of development and complexity, the responses elicited initially may lead to still other behaviors not previously associated with the task stimuli themselves. The task stimuli plus the consequences of initial response to them may produce solutions to problems (e.g., the algorithms of mathematics) simply because of a formal relationship among the stimuli that cues the required performance. While the verbal statement of the problem and the numerals they contain may be new to the learner, the relationship may be recognized as something that he has learned to label as a mathematical problem requiring the use of linear equations; this could be a sufficient cue to produce a complex set of responses involving information or data processing not previously practiced in the presence of the stimuli.

Included among the elicited responses are attention or receptor focusing skills and processing skills, many of which can be described in terms of formulas, algorithms or as rules or principles. Each of these, though complex in itself, nevertheless, can be an element of a more complex response.

Behavioral Structures

Originality. A number of experimenters, such as Royce (1898); Slosson and Downey (1922); Osborn (1957); Maier (1931, 1933); Judson, Cofer and Gelfand (1956); Maltzman, Brooks, Bogartz, and Summers (1958) and Bass, Hatton and McHale (1962) have investigated various training procedures in attempts to increase the frequency of original behavior. Thus, originality (often considered an aspect of creativity), as a form of performance on a variety of tasks, has been considered a transfer phenomenon as well as a human ability (Guilford, 1950). It is another example of non-specific transfer. Unlike the previous examples, it can transcend subject-matter boundaries. However, aptitudes, as treated here, are information processing abilities that apply to sets of tasks which have a common structural, or relational, characteristic. Originality is therefore considered as an aptitude, one involving abilities that generate a multiplicity of associations to a stimulus rather than a single association. This form of behavior can be elicited by a wide range of stimuli which do not necessarily relate to one another as elements of a content area. It can be cued by structural features of tasks that do not necessarily relate to one another semantically.

Logical skills. There are other task structures that elicit complex behavior chains or processing skills. One example of logical or reasoning skills is the syllogisms of logic. These structures have been studied and formalized; and, for example, there is a finite set of 256 syllogisms to which as few as four rules of validity can be applied. Thus, once an argument is identified as a syllogism, these rules can be applied to determine the validity of the argument whether it is presented in abstract or concrete form and, if in concrete form, regardless of the subject matter.

In transferring the information processing skills involved in the application of the rules of validity, the learner has to identify a complex structure (a set of relations among symbols) as a syllogism. To do this he may have to use other processing skills to translate words to symbols or to restate sentences. These processing skills are abilities which comprise the lower-level supporting skills involved in the ability mechanism for transfer in problem-solving whether it occurs in history, political science, or interpersonal relationships.

SUMMARY

The first phase consisted of a survey of the existent data and concepts for two purposes: (1) to summarize and integrate research and theory and to consolidate and interpret research findings; and (2) to consider these findings in relation to the problems of education so as to produce a set of hypotheses for research and a workable plan for conducting studies which relate to one another in a way that contributes to particular educational problems.

The procedure for Phase I was library research plus the analysis and synthesis of existing information and concepts. Reports, articles, monographs, and books were abstracted and an interpretive summary was prepared.

Preliminary empirical research was conducted using such instructional materials as logic, multiple correlation, and an artificial science. These empirical studies have dealt with the following basic problems in transfer: (1) sequencing, e.g., inductive (discovery) vs. deductive; (2) learning-how-to-learn; and (3) mediation theory.

The following sections present the summarizations of research and theory, the summaries of the preliminary studies relating to this plan, and the research plan generated by the work performed in Phase I.

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Chapter 2

OBJECTIVE 2: SOME PRINCIPLES OF TRANSFER

The following is a compilation of principles of transfer derived from a selected set of references. Quotation marks were not used because minor alterations were made in editing the summary statements of writers in the field.

The grouping of principles is under two major headings. The first is specific transfer; the second is non-specific transfer.

SPECIFIC TRANSFER

Performance Following Minimal Stimulus Change and Simple Responses

Stimulus Generalization

Probably the most basic transfer mechanism is stimulus generalization. Although there is some controversy about whether it takes place during learning or during its demonstration, there is no question of its existence. The main concerns are with the forms of the curves and the psychological mechanisms that underpin it.

> Stimulus generalization. The probability that a new stimulus will be followed by a previously-learned response is an increasing function of the similarity of the new stimulus to the stimulus to which the learned response was conditioned. (Hilgard, 1948;, McGeoch and Irion, 1952; Osgood, 1953; Bass and Hull, 1934; Humphreys, 1939; Guttman and Kalish, 1956; and Kimble, 1961.)

Stimulus intensity. If stimuli are the same except for intensity and ar similar in intensity, a response which is learned to one stimulus tends to be evoked more strongly by a stimulus slightly more intense than the one presented during learning. This is an exception to the general stimulus generalization principle. (Grant and Schiller, 1953.)

Associative shifting. A subject may give a response to a totally new stimulus by practice as the stimulus events are progressively changed. (Thorndike, 1913.)

Occurrence of an instrumental response. It is possible to increase the response required in an instrumental learning situation which has been associated with cues like those in the new, physical situation and is already associated with the existing motivation. As the response increases in probability, the speed of its selection becomes greater. (Osgood, 1953.)

Performance Following Changes in the Stimulus Context

Reorganizations from tension. The unstable, fluctuating pattern of tension in the psychological field tends to be minimized through sudden reorganizations (insight) involving the perception of new paths to the goal. Sub-principles: (1) Insight is more likely to occur if the goal tension is moderate than when it is excessive. (2) To the extent that the animal varies its position in the geographical field, the process of reorganization is facilitated. (Osgood, 1953; Kohler, 1925.)

The shorter paths. Animals will tend to choose the shorter of two paths to the same goal. (Osgood, 1953; Husband, 1931.)

Strength of tendency to choose the shorter path. The closeness of the goal object to the organism and the strength of its motivation determine the difficulty of the selection of the longer path (i.e., solution). (Osgood, 1953; Hull, 1938.)

Discrimination

While not usually considered as a transfer phenomenon, stimulus discrimination does involve prior learning. It is necessary for the learner to undergo discrimination training because of interference between the responses to the different stimuli. When two or more different stimuli are sufficiently similar to elicit the same response it might be true for either of two reasons. One reason is stimulus generalization; the other is acquired similarity coming from the learning of the same response to the set of stimuli. The problem in discrimination training is to eliminate the undesired response.

Conditioned discrimination. In classical conditioned discrimination experiments, it is somewhat more satisfactory to establish the response to the positive stimulus first, before the discrimination is undertaken. (Hilgard, 1951.)

Extinction of generalized conditioned responses. With subsequent testing, the generalized responses appear to extinguish more rapidly than those established to the original conditioned stimulus. (Hovland, 1951; Hovland, 1937.)

Discrimination problems and past learning. The learning of a particular discrimination problem is a function of the number of previously learned problems of the same general sort. (McGeoch and Irion, 1952; Harlow, 1949.).

Generalization and discrimination. The ease of obtaining discrimination between two stimulus situations is inversely related to the amount of generalization between them. (Osgood, 1953.)

Response Generalization

While generally accepted as a valid phenomena it is less well documented in research studies.

Response generalization. Once a given stimulating condition is connected with a particular response, it will elicit other responses which are related in some way to the first, or trained, response. (McGeoch and Irion, 1952; Robinson, 1932; Bekhterev, 1932; Kellogg, 1939; and Keller and Schoenfeld, 1950.)

Bilateral transfer. Positive bilateral transfer occurs in amounts varying from a small percentage to a very large one. This occurs over a range of activities so wide as to be a very general phenomenon. (McGeoch and Irion, 1952; Lashley, 1924; Bray, 1928; and Woodworth, 1938.)

Performance Following Changes in the Context

Shift of instrumental responses. Instrumental sequences may shift without any new learning as when a barrier is inserted, and the S leaps it. (Osgood, 1953; Wickens, 1938.)

Behavior during instrumental learning. Instrumental learning does not involve simple selection of an isolated response. It involves a complex shift in total behavior within the situation. (Osgood, 1953; Verplanck, 1956.)

Position in habit family hierarchy. The position in the hierarchy, and hence the probability of occurrence of a given response, varies with the degree to which it has previously been reinforced in similar situations. (Osgood, 1953; Hull, 1934; and Birch, 1945.)

Removal of Reinforcing Stimulus

When the reinforcing stimulus is removed, the behavioral process that is developed is called extinction. The term refers to the apparent elimination of the overt response previously known to be highly probable in the presence of a specific stimulus or class of stimuli.

Extinction. When a response is not followed by reinforcement, the tendency of the response to occur in the future, particularly if reinforcement has been provided on every trial is lower. (McGeoch and Irion, 1952; Hovland, 1937.)

Generalization of extinction. Stimulus generalization, as a phenomenon, applies not only to the effects of training, but also to the effects of extinction. (McGeoch and Irion, 1952; Hovland, 1937.)

Form of extinction curve. Extinction is typically a negatively accelerated function of the number of unreinforced repetitions of the stimulus. (Osgood, 1953; Reynolds, 1945.)

Successive extinctions. When a series of successive extinction sessions is applied, with rest interpolated, it becomes progressively easier to obtain any given extinction criterion. (Osgood, 1953.)

Resistance to extinction and partial vs. continuous reinforcement. If all other things are equal, resistance to extinction after partial reinforcement is greater than that after continuous reinforcement when behavior strength is measured in terms of single responses. (Jenkins and Stanley, 1950.)

Motivation and extinction. Increases in motivation are typically accompanied by increased resistance to experimental extinction. (McGeoch and Irion, 1952.)

Distribution and extinction. Massing trials during extinction has the effect of decreasing resistance to extinction or decreasing the tendency to respond on any given trial during extinction. (Deese, 1958; Gagne, 1941; Reynolds, 1945; Rohrer, 1947; and Teichner, 1952.)

Performance Following Moderate Stimulus Change and Simple Responses

Removal of Reinforcing Stimulus and Rest

After a series of extinction trials a rest can be introduced and then the cue stimuli can be reintroduced to see if the behavior reappears.

Spontaneous recovery. After extinction has been accomplished (to some arbitrary criterion), a period of rest (usually removal from the original situation) is followed by reappearance of the same response to the stimulus. (Osgood, 1953; McGeoch and Irion, 1952; Hovland, 1937.)

Amount of spontaneous recovery. Typically, the course of spontaneous recovery through time at rest is also negatively accelerated; recovery occurs rapidly at first and then tapers off as rest continues. (Deese, 1958; Osgood, 1953; Ellson, 1938.)

Removal of Reinforcing Stimuli and Novel Stimulus Interference

During the course of an extinction series, an extraneous stimulus can appear. If it does appear, the behavior that is being extinguished increases in strength and the internal process is referred to as disinhibition.

Disinhibition. Extraneous novel stimuli introduced during extinction temporarily raise the strength of the response being extinguished. (Osgood, 1953; McGeoch and Irion, 1952; Deese, 1958; and Hovland, 1931.)

Performance Following Specified Types of Stimulus Change in Paired-Associate Tasks

Stimuli Changed

Responses not changed. If paired-associates materials are unfamiliar, and if responses are identical and the stimuli are similar, then the relative number of trials required to learn the second list (% age) decreases with increased learning of the first list. (Osgood, 1953; Bruce, 1933.)

Responses are similar. If paired-associates materials are unfamiliar, responses are similar, and stimuli are identical, increased learning of the first list initially increases and then decreases the difficulty of learning the second list. (Osgood, 1953; Bruce, 1933.)

Responses are different. If paired-associates materials are unfamiliar, and if responses are either different or similar, and stimuli are identical, then the relative number of trials required to learn the second list tends to increase with increased learning of the first list. However, the amount of increase is less when the responses are similar than it is when they are different. (Osgood, 1953; Bruce, 1933.)

Performance in Relation to Amount and Type of Training

Amount of Training

Amount of practice on first task. In general, conditions yielding negative transfer do so when the training activity is learned to a relatively low degree, but as training increases the amount of negative transfer diminshes and may be superseded by positive transfer. (McGeoch and Irion, 1952; Ho, 1928; Cook, 1936.)

Relative amount of training and transfer (suggestive). The amount of negative transfer is greatest when the tasks are learned to a similar degree. (McGeoch and Irion, 1952; Siipola and Israel, 1933; Melton and Irwin, 1940; Sears and Hovland, 1941.)

Time Interval Between Tasks

Transfer and time between tasks. The amount of transfer between two tasks is independent of the length of time between practice on the two tasks up to an interval of 90 days. (McGeoch and Irion, 1952; and Bunch, 1941.)

Exception: Warm-up. Positive transfer between similar tasks will be greater if the second task is practiced immediately after practice on the first. The procedure of increasing an effect of time between the two practice sessions will be accompanied by a sharp reduction in amount of transfer; the effect is not dependent upon long practice or appreciable learning on the first task. (McGeoch and Irion, 1952; Hamilton, 1950; and Thune, 1950.)

Performance as a Function of Learner Factors

Age and retroactive inhibition. An irregular tendency for amount of inhibition to decrease with increasing CA from 8 to 16 has been found. (McGeoch and Irion, 1952; Lahey, 1937.)

NON-SPECIFIC TRANSFER

Performance Following Unspecified Stimulus Change and Complex Skills

General Principles Induced

The learner can be left to his own devices to "discover" a general principle or formal similarity among a set of materials or problems.

The principle of non-specific transfer. A factor, such as a principle or a method, which is non-specific to the training situation, tends to be elicited by similar situations. (McGeoch and Irion, 1952; Meredith, 1927; Woodrow, 1927; Salisbury, 1934; Barlow, 1937; and Stroud, 1940.)

Learning how to learn. Subjects quickly learn how to learn particular materials under specific conditions and may increase their rates of learning markedly. (McGeoch and Irion, 1952; Bunch, 1941; Osgood, 1953.)

Positive transfer occurs when general principles, techniques, or modes of attack apply equally to the tasks successively practiced. (Osgood, 1953; Starch, 1911; Poffenberger, 1915; Salisbury, 1934; and Siipola, 1940.)

Influence of the conditions of learning. As a result of the greater effort and vividness associated with independent discovery, transfer might be expected to be greater under this method. (Ausubel, 1961 a, b.)

Insight is often accompanied by a verbal formula which permits the principle to be applied readily to new problems. (Hilgard, 1948.)

A pattern of dynamic relationships discovered in one situation may be applicable to another. (Hilgard, 1948.)

Discovery. Discovery which comes directly from practice can result in greater transfer than can be achieved by demonstration, by explanation, or by rote learning. (Winch, 1913; Katona, 1940; Hendrickson and Schroeder, 1941; Haslerud and Meyers, 1958; Rowlett, 1960; Ausubel, 1961b, to contrary.)

Performance following the inductive method is significantly superior to that following the inductive-discovery method when they are compared after five weeks. The inductive-discovery-confirmation method results in transfer significantly inferior to that in all other methods after five weeks. (Tomlinson, 1962.)

Transfer to tasks requiring problem solving is significantly superior in the understanding group (S shown how to derive order following a written scheme or prompt). (Hilgard, Irvine and Whipple, 1953.)

Transposability of solutions. Solutions are transposable to the extent that their functional values are grasped. (Osgood, 1953; and Duncker, 1945.)

Learning and amount of practice. Practice at learning successive lists of verbal material brings a considerable increase in rate of learning. (McGeoch and Irion, 1952; Lepley, 1934.)

Set in rational problems. The set of the subject not only directs him toward an attack upon a rational problem but also determines to a considerable extent what prior knowledge he shall bring to bear on it (transfer of training) and how he shall attack it. (McGeoch and Irion, 1952; Pratt, 1928; Woodworth and Sells, 1935; Sells, 1936; Gibson and McGarvey, 1937; and Luchins, 1942.)

General Principles Deliberately Taught

The learner can be told to process the information given him, and the effects can be studied.

Instruction and abstract problem solution. Instruction in analysis, abstraction, and generalization produces a distinct positive transfer to problems requiring reasoning and understanding. (McGeoch and Irion, 1952; and Barlow, 1937.)

Transfer of general principles. The general principles involved in a learning situation are more apt to transfer to new learning situations if they are taught as general principles rather than as principles specific to the particular situation. (McGeoch and Irion, 1952; Judd, 1908; Coxe, 1923; Katona, 1940; Melton, 1941; and Hendrickson and Schneider, 1941.)

Transfer of set. If a set to perform is induced prior to learning, the rate of acquisition should be greater than if this set had not been induced. The amount of the increase in the rate of acquisition should be an increasing function of the similarity between the set-inducing task and the learning task, an increasing function of the amount of time devoted to the induction of appropriate set, or an inverse function of the time between the two activities. (McGeoch and Irion, 1952; Thune, 1950; and Hamilton, 1950.)

Transfer: Influence of the conditions of learning. If the learner has experience in applying the principles within a variety of tasks during learning, transfer is improved. (Adams, 1954; Harlow, 1953; and Dulaney, 1962.)

Instruction and set-recall. Instructing subjects to recall and to resist the effects of interpolated material aids them in recall. (McGeoch and Irion, 1952; Lester, 1932.)

Instructions and specificity of learning. Without any instructions, comprehension of material is only general; however, instructions that cover the details of content, the details of wording, or the sequence of individual events in the material to be tested produce highly specific learning. (Hovland, 1951; Postman and Senders, 1946; and Merrill, 1964.)

Effects of instructions in how to memorize. Experiments showed that in a case in which one kind of training, undirected drill, was used there were amounts of transference which were sometimes positive and sometimes negative but always small. Another kind of training with the same drill material may result in a transference, effects which are uniformly large and positive. (Hovland, 1951; Judd, 1908; and Woodrow, 1927.)

Instructions inducing set to respond. An effect of instruction is to arouse or produce a set which influences behavior in the direction intended -- that is, directs it. (McGeoch and Irion, 1952; Lester, 1932; Carmichael, Hogan and Walter, 1932; and Miller and Cole, 1936.)

Effectiveness of concrete proposals. The effectiveness of concrete proposals depends upon their functional value. (Osgood, 1953; and Duncker, 1945.)

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Chapter 3

OBJECTIVE 3: SUMMARY OF PRELIMINARY STUDIES

A. Transfer Effects of Different Kinds and Forms of Information Encoding

L. M. Stolurow, T. J. McHale, D. Mattson and D. J. Davis

A series of experiments was conducted to investigate the effects of two basic types of transfer of training in complex concept-formation tasks. Two different tasks were used which differed only in minor respects since each was generated from the same multiple-correlational model (see Azuma, 1960; Azuma and Cronbach, 1961; and Cronbach and Azuma, 1961). The two basic types of transfer of training were: (1) transfer to task performance from written instructions which differed in the amount of information they gave the learner, and (2) transfer from one task to the other where the relationships between tasks were specified. The latter included both two-stage and cumulative transfer (learning-how-to-learn) experiments. The study was designed to investigate several basic problems such as (1) the informational value of different task characteristics, (2) the effects of different ways of encoding task-relevant information, and (3) the development and role of verbal mediating mechanisms (hypotheses) of the learner both when learning and when transferring to new tasks.

Experiment I

Amount of Information Conveyed by a Knowledge of Either the Principle or the Cues Given in Algebraic Form

Status:	COMPLETED -- Thomas J. McHale and Lawrence M. Stolurow	More Information -- Cues or Principle? Technical Report No. 5, May, 1964.

PURPOSE

This experiment was designed to investigate (a) the amounts of information communicated by the knowledge of a principle as opposed to the knowledge of cues, and (b) the effectiveness of the knowledge of a principle as opposed to the knowledge of cues at different stages of learning.

Hypotheses

1. A knowledge of the principle is more beneficial than a knowledge of the cues since it is easier to learn the cues than it is to learn their proper weighting and formal relationship (principle).

2. A knowledge of the cues is more beneficial in the early stages of learning when the S must detect what is relevant, but a knowledge of the principle is more beneficial in the later stages of learning when the S must determine the appropriate weights and relationships for the relevant cues.

3. The rank order of performance for the four different groups to be tested is: full information, principle information, cue information, and no information.

RESULTS

The following conclusions about the experimental hypothesis were drawn:

1. A knowledge of the principle (principle group) is not more beneficial than a knowledge of the cues (cue group), although a knowledge of the principle together with a knowledge of the cues (full information group) leads to better performance; the final level of performance for the full information group, however, is not statistically better than that of the cue group.

2. When the principle and cue groups are compared, a knowledge of the cue does not seem to be more beneficial initially, nor does a knowledge of the principle seem to be more beneficial later in learning; however, the groups who knew the principle (full information and principle groups) did learn the relative importance of the two relevant cues better than the other groups.

3. The rank order of performance for the four groups was not as predicted, since the cue group performed better than the principle group. The difference between the two groups, however, was not significant.

RESULTS

The results of the experiment may be summarized as follows:

1a. A warm-up effect was identified. Ss who performed a series of four tasks quite different from the criterion task, using four cues unlike those used on the criterion tasks, solved the criterion task in fewer trials than Ss in the control group.

1b. A learning-to-learn effect was identified. Those Ss who received training on a series of training tasks which were similar to the criterion task solved the criterion task in fewer trials than the Ss who received training tasks dissimilar from the criterion task.

1c. No transfer effect was found for the repetition similarity of cues between the training tasks and the criterion task.

2. For some of the Ss, relevant and irrelevant cues remained constant for all tasks; for some Ss, relevant and irrelevant cues were reversed on the criterion task; and for some Ss, completely new cues were introduced during the criterion task. The number of trials needed to solve the criterion task was not affected by any of these three cue conditions.

3. The use of the same two cues in the solution of a number of training tasks resulted in an increased use of these cues on the first trial of the criterion task. The criteriality (correlation) between cues and responses was higher, on the first trial of the criterion task, for cues which previously had been relevant than for cues which previously had been irrelevant.

Experiment III

The Effects of Sequence and Structure on Complex Concept Formation

Status: COMPLETED -- Daniel J. Davis — The Effects of Sequence and Structure on Complex Concept Formation, Technical Report No. 4, January, 1964.

PURPOSE

Since there are several different principles which can be invoked in structuring or sequencing the training trials of a task, it is important to know the transfer effects produced by the different principles. In this study, four groups of Ss were given different training conditions, as specified by four different principles, in order to determine the effects produced in the learning of a transfer task.

Hypotheses[5]

1. Asynchronous trials result in a higher level of performance.
2. The better order of presentation of training trials is: first, synchronous trials, then asynchronous trials.
3. During the asynchronous trials, it is better to vary the relevant cue first.

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[5] See Detambel and Stolurow (1956) for a definition of asynchrony and synchrony.

RESULTS

1. A significant learning effect was found. Asynchronous training did not result in a significantly higher level of performance. This lack of difference may be ascribed to the lack of generalized learning due to training on only one member of the class of asynchronous blocks and/or the over-emphasis of the less relevant cue.

2. For the experimental groups, it was found that the presentation of synchronous training trials prior to asynchronous training (Groups 3 and 4 in Table 6) did not improve performance. Therefore, the hypothesis that this type of training would aid transfer (by familiarizing _S_s with the transfer task prior to asynchronous training) was not confirmed.

3. It was found that presenting a sequence in which the more relevant cue varied first led to improved transfer task performance. This indicates that the order of training in a complex task should proceed from the more relevant to the less relevant aspects.

Further Research

The conclusions reached in this experiment will serve as the basis for future investigations. In particular, the following questions are of interest:

1. How does the _type_ of asynchronous training affect transfer? It is expected that asynchronous training, which involves only maximally-pertinent cues, would be superior to that which involves only minimally-pertinent cues.

2. How does the amount of asynchronous training affect transfer? There are several issues here. First, there is the question of how much training should be given for each type of asynchronous block (e.g., keeping the cross in a fixed position for a block of trials while the circle varies from column to column. Second, there is the question of how many types of asynchronous blocks should be presented for optimum transfer. These two questions relate to the multiple problem, training issue, as discussed by Morissett and Hovland (1959). Third, there is the question of apportioning training among the more pertinent aspects. Is it better to decrease the amount of training for the less pertinent aspects of a problem as compared with the more pertinent aspects? There is some slight evidence that this is the case; a direct test of this hypothesis, however, is necessary before a definite conclusion can be made.

3. How does the order of asynchronous training affect transfer? It was demonstrated in this experiment that transfer is greater when the more pertinent cue is allowed to vary first. This suggests an order relationship in training which is based on the relevancy of the aspects. That is, the more relevant or pertinent aspects should be presented first. This should be demonstrated in the case of three or more aspects, each differing in its relevancy to the solution, before this order effect is accepted.

B. Learning and Transfer Effects Related to Instructional Variables and Test Conditions in Logic[6]

L. M. Stolurow, L. T. Frase, J. Odell, J. Zartman, J. Kearns, and G. Marco

A series of transfer experiments is being conducted utilizing self-instructional materials in an introductory logic course at the collegiate level, developed in the Training Research Laboratory.

Experiment I has both a substantive and a methodological purpose. The substantive purpose is to determine the relationship between personality (e.g., aggression, test anxiety) and ability traits, and the learning of introductory logic; the methodological purpose was to compare performance on open- and closed-book examinations.

Experiment II assesses the different effects of linear and branching programs upon the acquisition and retention of formal logic in terms of both knowledge and application test items.

Experiments III and IV study the systematic effect of congruous and incongruous conclusions upon syllogistic reasoning, demonstrating that verbal responses negatively transfer to reasoning, and that atmosphere and incongruity negatively effect judgments of the validity of syllogisms by Ss without training.

Experiment V attempts to determine the effects of two different formal symbolic notations (Peano-Russell and Polish) upon the acquisition and transfer of the knowledge and application of propositional logic.

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[6] Experiments and reports under this heading are to be completed in Phase II.

C. The Use of a Model and a Generalized Preview to Facilitate the Learning and Retaining of Complex Scientific Materials[7]

M. David Merrill

Status:	COMPLETED -- M. David Merrill	Learning and Retention Effects of a Model and a Preview in Teaching an Imaginary Science, Technical Report No. 3, November, 1963.

PURPOSE

Several competing principles concerning the organization of materials to promote learning and transfer exist in education and educational psychology. Programed instruction provides a useful medium for the examination of these principles since they can be used to prepare sequences of frames for comparative study. The effects of each can be determined readily in terms of performance differences of students. This study compares some competing notions about the way to organize complex materials. One program meets the organizational requirements of Ausubel's subsumption theory (1963) and three other logical alternatives were used.

Hypothesis

Based on Ausubel's subsumption theory and its implications for the use of "advance organizers," it was hypothesized that presenting a model and/or a preview prior to the presentation of complex verbal materials would facilitate the learning and retention of those materials.[8]

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[7] This study was done in partial fulfillment of the requirements for a Master of Science degree in education. A related study was completed as a doctoral dissertation: Merrill, M. D. Transfer effects within a hierarchical learning task as a function of review and correction on successive parts. Urbana, Ill.: Univer. of Ill., Trng. Res. Lab. NONR Contr. 3985(04), Tech. Rept. No. 5, September, 1964.

[8] The experimental program used is on file in the University of Illinois library; it is titled "Xenograde Systems: An Experimental Program" by M. D. Merrill (unpublished).

RESULTS

1. Results indicated no significant main effects. There were two significant interaction effects: (1) retention as measured by application items was best for high IQ _S_s when presented a model, but best for less gifted _S_s when no model was presented; and (2) retention as measured by items measuring taught knowledge was best when no model or preview was presented and poorest when only a model, but no preview, was presented.

Implications

An analysis of test performance seems to indicate that the teaching machine program was effective in teaching knowledge of terminology of specific facts but ineffective in teaching understanding necessary for problem solving. It would be desirable to replicate the experiment with a revised program which would enable students to attain a higher level of understanding as measured by problem solving ability.

Experiments and Reports Proposed for Phase II

A. Transfer Effects of Different Kinds and Forms of Information Encoding

- I. Amount of Information Conveyed by a Knowledge of Either the Principle or the Cues Given in Algebraic Form
- II. A Comparison of Transfer Effects from Written Instructions Under Paced and Self-Paced Conditions
- III. Some Perceptual and Verbal Factors in the Transfer from One Task to Another Generated from the Same Model
- IV. Some Perceptual and Verbal Factors in the Transfer from One Task to Another Task Generated from the Same Formula

B. Learning and Transfer Effects Related to Instructional Variables and Test Conditions in Logic

- I. Psychological and Psychometric Correlates of Achievement-Test Modes
- II. Learning and Transfer Effects of Linear and Branching Programs in Logic
- III. The Implications of Training in Logic for Incongruity and Atmosphere Effects
- IV. The Separate and Joint Effects of Congruity and Atmosphere
- V. Relative Transfer Effects of Learning Systems of Notation for Encoding Expressions in a Course of Programed Symbolic Logic

C. COMPLETED

D. Transfer Effects in Verbal Learning

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Chapter 4

OBJECTIVE 4: PROPOSED RESEARCH PROGRAM

GENERAL

The research program will be developed further, and this development is to be guided by the data and findings obtained during each phase of work. The initial phase has generated both results and plans. Subsequent phases will obtain most of their data from empirical studies rather than from literature surveys. Depending upon their potential importance to education and the state of the art with respect to technological and theoretical development, later phases will differ in length and level of activity. It may be necessary, therefore, to defer work on more important substantive problems until the answers to some less important technological problems or some techniques have been developed.

The new curriculum programs for schools, colleges, and professional training institutions involve many assumptions about the methods of accomplishing transfer which need to be tested. Furthermore, the meager but highly relevant information about transfer processes need to be summarized. Two fundamental curricular problems relate to transfer. One is the programing of a subject matter to teach facts and concepts; the other is the sequencing of materials to develop particular cognitive styles or learning strategies. While the former is concerned more with the formation of associative structures, the latter is concerned with the development and cueing of processing skills. These twin problems are not only present in all of the curriculum development projects, but are also basic to every one of them.

Phase II

The procedure in the second phase will be associated less with library research than it was in Phase I. There will be a marked increase in the amount of empirical research designed to elucidate transfer problems and processes.

A systems approach will be taken in the analysis and guidance of the learning and instructional conditions by which transfer is determined. The guidance of learning under replicable conditions can be accomplished through the use of a variety of media; furthermore, each can be an integral component of a computer-aided instructional system. Programed instruction and a computer-based instructional system will be used to provide a replicable and realistic instructional environment. The psychology of transfer is being studied in both fundamental and applied ways in order to explicate its facets through conceptual analysis and experimental study.

Transfer principles can contribute to both pretutorial decision making and dynamic tutorial decision making which takes place while the student is learning. Therefore, we examined correlational as well as experimental studies. The former are particularly relevant to the relationships between attitudes and learning -- to pretutorial decision making; the latter are particularly relevant to tutorial decision making.

Analysis of Instructional Procedure

In education and training, one important task of the teacher is building complex, structured behavioral repertoires which typically involve learning sets or classes of cue-response relationships. One basic research problem, therefore, is to determine efficient ways of building higher order learning sets, or conceptualizations, out of lower order ones by using different sequences of materials and different conditions of learning and responding. To do this, it is necessary to analyze the task as it is performed by a proficient person Then the component sub-tasks can be identified and put into a sequence that can be given to students in school. Mathematics, logic, and English tasks need to be identified and analyzed in terms of the hierarchical structures revealed by a content analysis. Each analysis can provide hypotheses about the organization of the training to be given to students in order to determine the transfer effects produced.

Task analyses. At a general level~~, the task~~ analyses can make use of Bloom's *Taxonomy of Educational Objectives* (1956) and Guilford and Merrifield's work on the structure of intellect (1960). This level of categorization can be reduced to more operationally-defined conditions by using Gagné and Paradise's (1961) learning set procedure; and, finally, the qualitative units can be mapped by Stolurow's (1964) task taxonomic procedures. Approaches to behavioral analysis as described by Mager (1961) will also be considered. These approaches provide useful materials for developing materials for either instruction or research. The development of a generalized conception of transfer that takes into account task characteristics in the development of learning materials is badly needed.

Problems to be examined. *One* set of problems consists in determining efficient methods of instruction and training over extended periods of time in teaching a school subject. This research relates to hypotheses dealing with sequencing of learning set materials (e.g., items in terms of class descriptive cues or of stimulus asynchrony) with the encoding of cues, the handling of prompts, knowledge of results, and the evaluations of responses.

Another set of research problems consists in determining the relevance and the use of associative structures in making decisions, both initially and during the course of instruction. Here, the concern is with the identification of abilities for the purpose of using them in the aptitude sense -- as knowledge about the learner both to predict and to optimize successful performance on new learning tasks.

A third set of basic problems consists in relating educational objectives to information about the student and to data about the effects of different instructional variables. The results of these relationships are for identifying models that interrelate the three sets of data in making instructional decisions.

Media Utilization

Programed instruction and a computer-based teaching system provide a medium for investigating the basic and applied problems of instruction; therefore, they satisfy the long-needed, laboratory-like conditions for studying the teaching-learning process *in situ*. This medium allows for not only the analytical but also the longitudinal study of transfer in on-going instructional settings. In addition, the individual factors that combine to produce the complex effects which occur when transfer takes place in school-learning situations can be controlled and examined separately.

Experiences with programed instruction have indicated that it is not only a feasible method of teaching, but also a valuable research tool ideally suited to the study of transfer. Media such as television, film, and magnetic tape also are useful; and, although they are more limited, they will be used, as appropriate, to provide experimental control and objective manipulation of variables. These media also will serve to provide a permanent record of the learning and transfer conditions used and will define objectively the procedures and conditions in a way that is difficult to accomplish when human teachers are used to study these processes. With programed instruction and film, effective techniques can be represented for teacher-training purposes. If developed into teacher-training materials, these materials could be important by-products of the basic research project.

Media integration: A computer based system. SOCRATES[9] was designed as a flexible, adaptive, cybernetic system for tutorial instruction. It is flexible with respect to the media which can be used in its student interface units. The input and output requirements of a task or set of tasks determine the nature of the link between the student and the computer. For instructional purposes, two basic problems are (1) the design of student interface units (the hardware problem); and (2) the design of the computer instructions which determine the decisions to be made and when they are to be put into effect (the software problem). An important by-product of the research engaged in on this project is that it will contribute to the solution of both the hardware and the software problems that must be solved for the effective utilization of the computer as a medium of instruction and of instructional research.

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[9] This is an acronym for "System for Organizing Content to Review And Teach Educational Subjects," a computer aided teaching system developed in the Training Research Laboratory of the University of Illinois under ONR Contract NONR 3985(04).

In the SOCRATES I configuration, the computer controlled the internal logic of 14 35 mm. film transport mechanisms[10] that had (1) rear screen projection, (2) selection response units that accepted 10 responses, and (3) 18 forward and backward film motions, any of which could be selected by the computer. In the SOCRATES II configuration, the computer controls 13 MASTER[11] I/O stations that have (1) rear screen projection,[12] (2) 15 keys which can be used for selection or constructed response, (3) random access to any one of the 1,500 35 mm. film frames controlled by the MASTER I/O station control logic, (4) separate message readout for knowledge of results, and (5) interval timing that permits control over the onset, duration and termination of the displays.

SOCRATES, as a flexible system of an educational media laboratory, can accommodate a variety of specific media (e.g., 35 mm. film, CRT displays, tape-audio system) and can also interrelate media to form a system for instruction in which each element serves a selected function.

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[10] This component was an AutoTutor Mark II manufactured by U. S. Industries and modified for SOCRATES at the University of Illinois.

[11] Monitored and Adaptive Socratic Tutor for Educational Research.

[12] The film transport and projection system of the AutoTutor Mark II was retained for this capability.

Furthermore, it provides a capability both for carrying out a complete set of instructional decisions and for processing the large amount of data which is accumulated during the extended learning and transfer experiences of groups of individually taught students.

Use of SOCRATES to study transfer effects. By using SOCRATES, it is possible to conduct studies of the transfer effects of pretutorial decisions about teaching methods based upon aptitude, ability, and personality information. Individual differences information will be used in making decisions about the treatment to be used to teach a defined set of concepts and a body of information. One type of treatment will be designed to compensate for the student's deficiencies in order to increase his ability, whereas an alternative treatment will be designed to capitalize on the student's existing strengths. These treatments will be examined in relation to age because different alternatives may be desirable for different age groups; e.g., compensate for low abilities early and capitalize on high abilities later.

A series of transfer studies will be concerned with treatments which relate to tutorial decisions. SOCRATES will be programed to use different decisions with comparable students, depending upon the data it obtains from the students while they learn. Thus, the computer will learn about students while it teaches them; the rules of this dynamic decision making will define the treatments used. One series of studies on dynamic decision making to develop behavioral structures for transfer will deal with the alternative decision rules for organization of steps.

Another series of studies will deal with variations in feedback (e.g., response evaluation and delays in knowledge of results) in which the concern will be the stability and strength of the behavioral structure as revealed by retention and transfer scores.

RESEARCH PROGRAM

The general assumption is that the language used (the particular set of symbols including pictures) in teaching a concept can be treated as a set of variables which differentially affect the nature of the behavior that results in learning and transfer. It is further assumed that the variables can be studied most effectively with a computer aided instructional system.

Encoding and sequence problems arise in a variety of contexts and have obvious educational media implications. Every medium requires that some form of encoding be used to represent the concepts to be taught, and that the material be organized into a particular sequence. Several studies provide data on these characteristics of tasks with respect to transfer within a subject matter. These studies also will provide information concerning the value of aptitude data for forecasting learning and transfer scores of students under different learning and transfer conditions.

Encoding Factors

One study will concern the hypothesis that differences in the structural similarity of two language systems will result in different amounts of transfer. To test this hypothesis, the rates of learning and transfer of students who have different educational backgrounds and aptitudes will be compared. Mathematical and verbal aptitude scores will be secured for all subjects. Students who have studied a great deal of mathematics will be compared with students who have studied very little mathematics. The comparison will be in terms of the rate of learning differently encoded logical concepts. The group of subjects will be divided into two subgroups. One will study a set of logical concepts from one version of the logic program (Peano-Russell notation); the other subgroup will study the other version (Polish notation). Half of each subgroup will be transferred to problems expressed in the other notational system. The problems will be different from those originally taught; however, all problems will be capable of being solved with the concepts and techniques taught. The transfer tasks will require the students to use not only the language of logic he learned but also the other form of symbolic encoding.

Of primary interest in this study is the extent to which the form of encoding used in learning logic affects the student's rate of learning logical concepts and the transferring of what was learned. It is hypothesized that there will be differences in correlation between verbal and mathematical aptitudes and the scores on the two transfer tasks following each condition of learning. These correlations will reveal the extent to which instructional decisions can be made more efficient for a particular student by selecting the form of encoding to use in teaching him on the basis of his aptitude scores. If the Peano-Russell notation, for example, is more readily learned and applied by students who have higher mathematical than verbal aptitude scores, but the Polish form of encoding is more efficiently learned and used by students who have higher verbal than mathematical aptitude, then the structural similarities of the two codes would appear to be an important factor in transfer. This finding would provide support for the hypothesis that the form of encoding is important in making the structural features of tasks more salient as cues. It also would provide a basis for making pre-tutorial instructional decisions involving the form of program to use. A test of the hypothesis could use a self-instructional program in logic to extend work begun with a multiple correlational task (Mattson, 1963; Davis, 1964; McHale and Stolurow, 1964).

Concept Sequence in Relation to Aptitude

Studies involving logic. Another study using the logic materials concerns the sequence in which concepts and skills are taught by comparing two sequences. In one sequence, syllogistic reasoning will be taught before symbolic logic. In the other sequence, symbolic logic will be taught first and then syllogistic reasoning. The latter sequence is suggested by the generality of the concepts; the instructional strategy is that of teaching the more general concepts first. The former sequence is the historical order in which the concepts were developed, and the instructional strategy is that of teaching the specific before the general.

These instructional strategems have been implicit in many teaching programs, but explicit in only a few. The purpose in working with them is to determine their relative effectiveness for transfer of training

Studies involving English. Related to the studies using the logic materials will be studies using materials to teach English vocabulary or word attack by the analysis of the roots and prefixes of words. The program teaches vocabulary by analyzing words into Latin roots and prefixes. It will be used with students who have had different amounts of Latin and one group that has had no Latin at all. Scores on Latin tests also will be used in correlations if they are reliable. After the students have completed the program, transfer will be determined by giving the students words, not included in the instructional material, for which the meaning could be determined if the analytical processes taught by the program were used to examine prefixes and roots. If Latin training provides transfer, then the means of the groups differing in amount of formal training in Latin should show a correlation with the amount of Latin studied. In addition to group differences, correlations will be obtained between aptitude (verbal and quantitative), amount of Latin studied, and scores on the learning and transfer tasks. If the general skills of word analysis are useful, then the students who have not studied Latin should perform equally as well on the transfer tasks as those who have.

Tutorial Conditions in Transfer

Transfer is dependent upon the quality of learning that has taken place. The quality of learning is established by several factors, such as

(1) the performance standards met by the student in learning; (2) the criterion used in giving knowledge of results; (3) the basis for providing evaluative feedback; (4) the overlearning criterion used; (5) the procedure used in withdrawing stimulus supports (fading, vanishing, prompt or guidance removal); and (6) the encoding of the concepts and information studied.

Overlearning. Although it is well established that there is a positive relationship between the amount of practice on the first task and the amount of positive transfer that results in learning the second task (McGeoch and Irion, 1952), there are no data to indicate the optimum amount of practice or overlearning to give the student on the learning task before he is given the transfer task. Furthermore, there are no norms to indicate the amount of overlearning that is optimum for different aptitude levels. This problem will be studied using the experimental designs of proactive and retroactive interference.

Sequence and length. One study, with the proactive design, might use a set of concepts to be taught to each group in one of two different sequences. In this case, the effects of the difference in sequence would be looked at in terms of transfer which would be measured by the student's rate of learning a new set of concepts. The transfer task would be the same for both groups. One learning sequence would present similar concepts grouped together [e.g., class descriptive cues would be used to group materials (see Stolurow, 1956; Wulff and Stolurow, 1957)] while the other sequence would present the same concepts arranged so that the set of concepts learned at any one time would be maximally dissimilar (the principle of asynchrony will be used). An additional variable in this design would be the *length of the task*, varied by using a different number of concepts taught at one time. This variable could be assigned a set of values, one for each length of lesson; e.g., 4, 8, 16, 32, and 64.

Another series of studies will deal with treatment comparisons based upon cognitive grouping of frames vs. various alternatives such as spiral sequencing, class-descriptive cue cluster, random grouping, and student-determined clusters.

Task interference. Other studies also will be designed to reveal the applicability of basic laboratory research on proactive interference for education and will provide an opportunity to study the relationship between proactive interference and retention (which Undersoon, 1957, considers more critical than retroactive interference as a factor determining retention). In these studies, a fifth-grade arithmetic program in fractions which teaches 14 concepts, and a statistics program which teaches concepts and computational skills for the mean, median, variance, standard deviation, correlation, etc., could be used.

Research will be designed to compare groups to which a set of concepts will be taught in alternative sequences, permitting analyses to determine the effects of proactive and retroactive interference. In addition, experiments will be designed to determine whether learning-how-to-learn effects (cumulative positive transfer) or proactive interference (cumulative negative transfer) occur within the context of subject matters such as logic, statistics, or mathematics.

Cultural effects. Consideration will be given to the feasibility of cross-cultural and interlingual studies in order to determine the generality of the principles of transfer. For example, in one culture, programed materials organized in terms of a Ruleg conception could result in more transfer than the same steps organized in terms of a discovery conception; in another culture, the reverse could be true. Other studies will deal with variations in the discovery treatment; i.e., cue discovery, principle discovery, and response discovery.

PROCEDURE

A Sample Plan for Experimental Studies

Subjects. Subjects will be drawn from different age and ability levels and, if feasible, from different cultural settings. The specific sampling procedures will be determined by the requirements imposed by the problem under study. Since aptitudes and abilities are an important set of data in the SOCRATES decision model, these data will be obtained uniformly and, in some studies, will be the basis for stratifying the sample of students used. Cultural differences also will be used in other studies and, if possible, sampling conditions will be duplicated (where replication of earlier studies is being accomplished) to check critical findings. Where long-term transfer is being studied and students participate over an extended time period, statistical adjustment may be required to compensate for losses in the sample.

Treatments. As indicated, the initial studies will use programed materials in logic, mathematics, statistics, and language. These areas have been selected because they represent formal systems developed to solve complex problems. The proposed transfer studies will investigate cognitive, dispositional, and strategy skills. Since these are information-processing skills, they can be thought of as contributions to the student's cognitive style, and can be used in combination with a wide variety of different subject matters. The texture of these structures will be studied to determine ways of cueing them to content learning sets.

Controls. The programed instructional procedure of employing a computer-based teaching machine system (SOCRATES) will be used as the primary means of controlling the treatments for stability of presentation. In addition, printed programed materials will be employed whenever participating student groups are in locations remote from the laboratory. Both the filmed frames and the printed frames meet the necessary requirements for replicability of conditions.

Students will be assigned to treatments randomly in order to achieve both representativeness and comparability among groups. Where appropriate, aptitude, personality, knowledge, socio-economic, and cultural factors are to be used to control individual differences.

Use of behavioral data. The use of a computer-based system will permit simultaneous monitoring of data concerning student ability, aptitude, and personality on the input side and relate it to response speed, accuracy, and attitudes on the output side. Furthermore, the developing relationships between input and output can be used either collectively or selectively to make different types of decisions regarding the very next step of a program. The decisions can relate to instructional procedures such as review, skipping, evaluation of performance, degree of student control of subsequent learning experience, pacing, difficulty, level of materials, etc.

Several different performance outcomes will be considered: (1) learning new and related material; (2) problem solving in which the knowledge taught is directly relevant and sufficient; (3) problem solving where the knowledge taught is not necessary, but the strategy required is relevant and useful; and (4) inferring and extending the knowledge taught to new materials.

Transfer effects are evidenced not only in the development of hierarchical structures of content learning sets, but also in the degree to which these are interlaced with dispositional and attitudinal learning sets. Measures of these interrelationships will be accomplished in the manner described by Gagné and Paradise (1961).

Performance prior to, during, and following learning will be measured by test instruments appropriate for the particular study. Evaluations made prior to exposure to selected learning conditions (instructional strategies) will be used to predict the direction and amount of transfer of training. Standardized tests of ability, aptitude, and personality will be used in addition to specially-designed tests which determine the level of each student's entry behavior. Evaluations will be made of the nature and extent of learning, retention and transfer. Following learning, broadly-based standardized tests and specific tests of terminal behaviors will be used.

The computer will use the students' latencies and errors (as related to particular segments of a self-instructional program) in making decisions about subsequent learning experiences. These data can be related to the students' aptitudes and personality test scores as a data pool to be used in making dynamic decisions. Alternative models will be studied to determine their relative worth as bases for decisions about instructional strategies where positive transfer is the desired outcome.

Statistical analyses. Analyses of variance, correlational techniques, and estimation procedures will be used. Analyses of variance will be used when hypotheses are tested. Correlational analyses will be used to determine relationships between input-output variables such as (1) ability test scores and learning task performance measures, (2) aptitude and retention, and (3) verbalization measures of understanding and transfer. Where appropriate and necessary, covariance and partial correlation will be used to assist both in making decisions and in the interpretation of findings. Residual scores will be used to measure gain (see DuBois, 1962) as a dependent variable.

Approximate Time Schedule

Phase I required two calendar years, ending June 30, 1964. The literature review which began at the initiation of Phase I will continue, but at a reduced level. The incorporation of the computer-based teaching machine system into the research plan has suggested the relevance of new areas of information. Bibliographies and abstracts of studies are being compiled and several summaries are being written in anticipation of their completion by the fall of 1965. The bibliographies and abstracts will be coded for storage and retrieval within the computer; the coding systems to be developed for this purpose should be in operation by July, 1966. This coding and computerization will make the literature relating to transfer available to research workers in a form that is responsive to individual study needs. Literature relating to the new media also will be coded and abstracts for computer storage and retrieval will be prepared.

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APPENDIX

LIST OF ARTICLES ABSTRACTED

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GENERAL

AUNOULT, M.D. STIMULUS PRE-DIFFERENTIATION: SOME GENERALIZATIONS AND HYPOTHESES. PSYCHOLOGICAL BULLETIN, 1957, 54, 339-350.

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